Channel Quality Assessment Method and System for Performing the Same

Priority is claimed from U.S. provisional patent application serial number 60/291,395, filed on May 14, 2001, entitled "Channel Quality Assessment", which is incorporated herein by reference in its entirety.

Field of the Invention

The present invention relates generally to frequency hopping spread spectrum communications, and especially to channel quality assessment responsive to random interferences in an FHSS communications system.

BACKGROUND OF THE INVENTION

In wireless communication systems, a specific frequency band is assigned for the operation of the specific system. In general, the frequency band is divided into a number of frequency channels, and each of the channels only occupies a fraction of the whole band. In a narrow-band communication system, the transmitter and receiver will select one channel for signal transmission. In a frequency-hopping spread spectrum (FHSS) communication system with adaptive frequency hopping (AFH), the system has to first determine the quality of each channel. The major impact to the channel quality is interference. The quality of a channel becomes bad if the frequency range thereof is overlapped with an interference source.

There are various types of interferences. Some typical interferences have bandwidths narrower than that of a channel. Others may have bandwidth that span from several to tens of the channels. Normally, the receiver only detects in a single channel each time, and switches from channel to channel to make a number of detections. Conventionally, the channel quality assessment for a channel is done by collecting the detections of this channel

and is independent from the detections of other channels. As the number of channels becomes large, the total time for channel assessment for all channels becomes very long. Referring to Kwang-Cheng Chen, Hung-Kun Chen, and Chi-Chao Chao, *Selective Hopping for Hit Avoidance*, in IEEE P802.15 Working Group Contribution, IEEE 802.15-01/057r2, March 2001, a method for channel quality assessment is disclosed, wherein the channels are divided into three partitions and each partition is treated as a whole. This method proves much faster for channel assessment, but much of the frequency resolution is unfortunately lost.

SUMMARY OF THE INVENTION

Accordingly, there is a need for a channel quality assessment system having a short assessment time and concomitant good frequency resolution.

To achieve this, the present invention provides a channel quality assessment method and a system for performing the method used in a frequency hopping spread spectrum communication system. The communications system has a plurality of channels for receiving signal packet traffic utilizing a plurality of receiving signal slots based on a hop sequence. The method comprises the following steps. A plurality of channels are grouped into a plurality of groups, and each of said plurality of groups has a plurality of channels. Channel quality of each of said plurality of channels is determined from detection results of each of said plurality of groups.

The various objects and advantages of the present invention will be more readily understood from the following detailed description when read in conjunction with the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a general system block diagram of the present invention. Fig. 2 shows a general system block diagram for one embodiment according to the present

invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 is a general system block diagram schematically illustrating the preferred embodiment of the present invention 100. A frequency synthesizer 101 provides a continuous sinusoidal frequency into mixer 120, the frequency being determined by a channel number 111 provided by a channel number generator 110 and inputted into mixer 120. The channel number 111 typically is derived from a hopping sequence generator in a FHSS system algorithm. In a narrow-band communication system without a hopping sequence, it comes from a sequence or an algorithm specifying the sequence of channels to detect. An RF input signal 112 is mixed at mixer 120 with the signal from the frequency synthesizer 101, the signal 112 in a desired channel being converted to a lower and fixed intermediate frequency (IF). Thus the frequency synthesizer 101 and mixer 120 together perform a channel selection function. A channel interference detector 102 performs channel interference detection and distinguishes among interference events, interference-free events and other unknown events generating detection/unknown event 126. A grouping/channel quality assessment unit 103 groups some channels and which are collected as whole in order to determine the channel quality. In the preferred embodiment of the present invention, the channel quality is determined by an interference collision ratio, which is the ratio of the number of interference events to the sum of the number of interference events and interference-free events.

As the system is using the k-th channel, some channel interferences are made by the channel interference detector 102 whereby the detection gives an indication about an interference event or an interference-free event. Another possible outcome is an unknown event which occurs when channel interference detector 102 does not have sufficient confidence to make decision between an interference event and an interference-free event. Integrated and/or co-located systems 130 also may affect interference, so integrated/co-located system information signal 132 is also input to grouping/channel quality assessment

unit 103 to produce a channel quality assessment 140.

Channel interference detector 102 utilizes two schemes for detecting interference, each of which is an embodiment of the present invention. The first embodiment checks the power level of a received signal packet 125. Received packets with lower power are more likely to have errors caused from noise, and these packets are indicated as unknown events. Packets with a power level exceeding a threshold are demodulated and checked for errors. The existence of error in a packet can be found by the error detection capability in the received signal packet 125. In the present invention, HEC (Header Error Check), CRC (Cyclic Redundancy Check) and FEC (Forward Error Correction code) areused for error detection. The signal packets 125 having errors are determined to be interference events, while signal packets 125 having no errors are determined to be interference-free events. Algorithmically, the channel interference detector 102 performs in this embodiment as follows:

Step1: Determine that a signal packet is an unknown event if the received signal power of the signal packet is below a predetermined threshold.

Step 2: Determine that a signal packet is an interference event if the received signal power is above the predetermined threshold *and* an error is detected in any one of HEC, CRC, and FEC.

Step 3: Determine that a signal packet is an interference-free event if the received signal power is above the predeterimined threshold and no error is detected in all of HEC, CRC, and FEC.

The second embodiment scheme utilizes the channel silent time between the channel active time. The channel silent time is the interval when there should be no transmission in the system and the signal strength in the channel silent time is measured. The channel interference detector 102 determines an interference event if the signal strength exceeds a predetermined threshold, otherwise it indicates an interference-free event. Algorithmically, the channel interference detector 102 performs in this embodiment as follows:

Step 1: Measure the received signal strength in the channel silent time.

Step 2: Determine that the received signal is an interference event if the received signal power is above a predetermined threshold.

Step 3: Determine that the received signal is an interference-free event if received signal power is below a threshold.

Grouping/channel quality assessment unit 103 performs channel quality assessment 140 utilizing several different embodiments according to the present invention. In one embodiment, the detection event 126 from channel interference detector 102 of one channel does not affect another channel. To obtain an interference collision ratio for each channel, the grouping/channel quality assessment unit 103 counts the numbers of interference events and interference-free events in detection/unknown event 126 for each channel in a given period of time while it discards other detection/unknown events such as unknown events. Grouping/channel quality assessment unit 103 then calculates the interference collision ratio for each channel as the ratio of the number of interference events to the sum of the number of interference events and the number of interference-free events.

A reliable determination by channel interference detector 102 requires seeing K detection events for each channel. If the number of channels is N, the total detection events for all channels are K*N, which becomes large with a large number of channels, N. This implies that the total time for channel quality assessment is long.

In the simple grouping embodiment of the present invention, the N channels are divided into P groups, and each group has an almost equal number of channels. Any event of a channel within a group is treated as an event of this group. To get an interference collision ratio for each group, the grouping/channel quality assessment unit 103 counts the number of interference events and interference-free events in detection/unknown event 126 for each group in a predetermined period of time while it discards other events such as unknown events. Grouping/channel quality assessment unit 103 then calculates the interference collision ratio for each group as the ratio of the number of interference events to the sum of the number of interference events and the number of interference-free events. Furthermore,

an integrated / co-located system 130 provide an integrated / co-located system information 127 which includes some information about the system to help the grouping / co-located channel quality assessment unit to assess the quality more precisely.

For reliable determinations, K detection events from detection/unknown event 126 for each group need to be checked. Since the number of groups is P, the total detection events for all groups are K*P, which is much smaller than the case of no grouping, since P is usually much smaller than N. Thus amount of data necessary for the channel quality assessment can be reduced substantially. On the other hand, this will produce a poor frequency resolution; that is, perhaps some channels are good and some others are bad in a group, but this embodiment can not present such information.

Another embodiment of the present invention addresses interference having wide bandwidth utilizing a grouping of many channelsto help to speed up the channel quality assessment. For the case of narrow-band interference an embodiment of the present invention utilizes grouping into one channel; i.e., no grouping. The preferred embodiment of the present invention achieves the desirable features of fast assessment and high frequency resolution. The preferred embodiment thus generalizes the grouping concept; that is, each group can have a different number of channels, while there can be overlapping between groups. Table 1 illustrates this idea.

<table>
<tr><td rowspan="3">Group number</td><td></td><td colspan="5">11</td><td></td><td></td><td></td></tr>
<tr><td colspan="3">9</td><td></td><td colspan="3">10</td><td></td><td></td></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td>Channel number</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td></tr>
</table>

Table 1

In this embodiment, there are some groups (groups 0, 1, 2, 3, 4, 5, 6, 7, 8) containing exactly one channel, and other groups have more channels groups 9, 10, and 11). Some groups are overlapped with other groups, for example, group 11 is overlapped with group 9 and 10 in channels of 1, 2, 4, and 5. If K detection events are necessary for determining an effective interference collision ratio, then the time period for collecting K event in group 11 is generally only one fifth of that group 1. Therefore, the speed for determining channel quality is increased. However, since interference occurs statistically, therefore by this method, the interference is detected quickly and thus the communication system can quickly adjust the required schemes, such as determining a hop sequence, so as to achieve high communication quality. There are some types of groups that are more effective according to the following guidelines. Groups can contain one or more of the following (but they are not restricted to the following list): (a) only one channel in a group, (b) divide all the channels into groups having equal size, and (c) groups can be organized to match the frequency range of some types of known interference. The interference collision ratio calculation requires the collection of K detection events in a group. Thus for each group, two counters are needed. One is to count the number interference events of this group, while the other is to count the number of interference-free events of this group. Each time the sum of the two counters reaches K, the interference collision ratio is calculated by the ratio of the number of interference events to the sum of the number of interference events and the number of interference-free events. A storage element of the last interference collision ratio of this group is then updated to the calculated ratio. A last value of interference collision ratio is kept for each partition. If this ratio is higher than a predetermined threshold value, the group is an interfered group. If a group G is overlapped with another group that is an interfered group I, and the size of group I is smaller than that of group G, then the overlapping channels in the group G are disabled; this is known as *group channels disable*. That is, the size of group G is reduced. As an example from Table 1, if the previous interference collision ratio value of group 1 is higher than the threshold, group 1 is marked as an interfered group. Then channel 1 in the group 9 and group 11 is disabled. The effective coverage of each group is shown in Table 2.

Group number		Disable	11						
	9	Disable	9		10				
	0	1	2	3	4	5	6	7	8
Channel number	0	1	2	3	4	5	6	7	8

Table 2

If a narrow-band interference is only in the range of channel 1, the interference collision ratio of group 9 may also exceed the threshold. The present invention remedies this if it is known that channel 1 is interfered from its last interference collision ratio, the overlapping channels from the groups with larger size being excluded. Each channel is given an interference collision ratio by the following technique. Since groups may overlap, a rule is needed to determine the interference collision ratio for a channel if it is contained in several different groups. The rule is as follows: The interference collision ratio of a channel is the interference collision ratio of the group that satisfies all of the following conditions: (a) the group contains this channel, and this channel is not disabled in the group, and (b) the group has the largest number of non-disabled channels.

In some cases, several communication systems, which can be interfering sources to each other, are built co-located or integrated 130. In these cases, information 132 related to the specific interfering system is passed directly to the interfered system according to the present invention. The procedure is to (1) get information from the co-located or integrated interfering system; this information includes one or more of the following: (a) the frequency channel, (b) the traffic load, (c) the received signal power. (2) From the information from step (1), obtain the channels overlapped with this interfering system, and obtain an interference collision ratio for these overlapped channels. (3) For these overlapped channels, select the larger of the inference collision ratios obtained in step (2)

and that obtained by the method described above.

Figure 2 is a schematic block diagram showing an embodiment of an adaptive frequency hopping (AFH) communication system wherein the channel partitioning block 220 serves to put channels having values of interference collision ratio within a predetermined range into the same one of partitions and outputs a partition sequence 221 into the AFH hopping sequence generator 210. One embodiment of the partitioning is to put channels into two partitions, good or bad. Another embodiment of the partitioning is to put channels into three partitions, good or bad or unused. AFH hopping sequence generator 210 has an input of partition sequence 221 from the channel partitioning block 220 and generates an adaptive frequency hopping sequence 211 which is then inputted to a channel number generator 110. The AFH hopping sequence generator 220 is to adaptively generate hopping sequence, based on the result of channel partitioning. The other blocks, such as channel number generator 110, frequency synthesizer 101, mixer 120, channel interference detector 102, grouping / channel quality assessment unit 103 and integrated / co-located systems 130, have functions identical to those disclosed in Fig. 1, and thus the details thereof will not be described here.

While the above is a full description of the specific embodiments, various modifications, alternative constructions and equivalents may be used. For example, the concepts described in the present invention are suitable for any communications system implementable in a frequency hopping spread spectrum system. Further, any implementation technique, either analog or digital, numerical or hardware processor, can be advantageously utilized. Therefore, the above description and illustrations should not be taken as limiting the scope of the present invention which is defined by the appended claims.